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Systematic Review

**LA RELACIÓN ENTRE LA COMPETENCIA MATEMÁTICA Y LA  
COMPETENCIA MOTRIZ EN LA EDUCACIÓN INFANTIL: UNA  
REVISIÓN SISTEMÁTICA**

**THE RELATIONSHIP BETWEEN MATHEMATICAL COMPETENCE  
AND MO-TOR COMPETENCE IN EARLY CHILDHOOD  
EDUCATION: A SYSTEMATIC REVIEW**

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REVISÃO SISTEMÁTICA**

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## LA RELACIÓN ENTRE LA COMPETENCIA MATEMÁTICA Y LA COMPETENCIA MOTRIZ EN LA EDUCACIÓN INFANTIL: UNA REVISIÓN SISTEMÁTICA

## THE RELATIONSHIP BETWEEN MATHEMATICAL COMPETENCE AND MOTOR COMPETENCE IN EARLY CHILDHOOD EDUCATION: A SYSTEMATIC REVIEW

### RESUMEN

Esta revisión sistemática explora la relación entre la competencia matemática y la competencia motriz en la educación infantil, un área de creciente interés debido a sus implicaciones en el desarrollo cognitivo y académico. Tanto las habilidades motrices finas como las gruesas se han propuesto como factores clave en la adquisición de competencias matemáticas tempranas, como el reconocimiento de números, el conteo y el razonamiento espacial, en niños y niñas de entre 3 y 6 años. Para investigar esta relación, se realizó una búsqueda sistemática en cinco bases de datos internacionales, Web of Science, Scopus, Dialnet, PsycINFO y ERIC, utilizando descriptores específicos relacionados con las matemáticas y las habilidades motrices. Se aplicaron criterios de inclusión centrados en estudios empíricos con participantes en edad preescolar. De los 5407 registros recuperados inicialmente, 12 estudios cumplieron todos los requisitos metodológicos y fueron incluidos en la síntesis final. Los hallazgos sugieren que las habilidades motrices finas están asociadas con la representación numérica y la escritura de números, mientras que las habilidades motrices gruesas se relacionan con la conciencia espacial y la estimación. Las intervenciones que combinan actividad física con instrucción matemática demostraron efectos positivos en el aprendizaje de las matemáticas, especialmente en niños y niñas con dificultades en la comprensión numérica. Sin embargo, debido a la heterogeneidad metodológica de los estudios, no fue posible realizar un metaanálisis. Estos resultados subrayan la necesidad de realizar más investigaciones con diseños sólidos que clarifiquen los mecanismos que vinculan el desarrollo motriz y matemático en la educación infantil.

**Palabras clave:** competencia matemática; competencia motriz; infancia; habilidades psicomotrices; aprendizaje matemático; desarrollo cognitivo.

### ABSTRACT

This systematic review explores the relationship between mathematical competence and motor competence in early childhood education, an area of growing interest due to its implications for cognitive and academic development. Both fine and gross motor skills have been proposed as key contributors to the acquisition of early mathematical abilities, such as number recognition, counting, and spatial reasoning, in children aged 3 to 6 years. To investigate this relationship, a systematic search was conducted in five international databases, Web of Science, Scopus, Dialnet, PsycINFO, and ERIC, using specific descriptors related to mathematics and motor skills. Inclusion criteria were applied to focus on empirical studies involving preschool-aged participants. Of the 5407 records initially retrieved, 12 studies met all methodological requirements and were included in the final synthesis. The findings suggest that fine motor skills are associated with numerical representation and number writing, while gross motor skills relate to spatial awareness and estimation. Interventions combining physical activity with mathematics instruction demonstrated positive effects on math learning, particularly in children with difficulties in numerical understanding. However, due to the methodological heterogeneity among studies, a meta-analysis was not feasible. These results underscore the need for further research with robust designs to clarify the mechanisms linking motor and mathematical development in early education.

**Keywords:** mathematical competence; motor competence; childhood; psychomotor skills; math learning; cognitive development



## A RELAÇÃO ENTRE A COMPETÊNCIA MATEMÁTICA E A COMPETÊNCIA MOTORA NA EDUCAÇÃO INFANTIL: UMA REVISÃO SISTEMÁTICA

### RESUMO

Esta revisão sistemática explora a relação entre a competência matemática e a competência motora na educação infantil, uma área de interesse crescente devido às suas implicações no desenvolvimento cognitivo e acadêmico. Tanto as habilidades motoras finas quanto as grossas têm sido apontadas como contribuintes essenciais para a aquisição de competências matemáticas iniciais, como o reconhecimento de números, a contagem e o raciocínio espacial, em crianças de 3 a 6 anos. Para investigar essa relação, foi realizada uma busca sistemática em cinco bases de dados internacionais, Web of Science, Scopus, Dialnet, PsycINFO e ERIC, utilizando descritores específicos relacionados à matemática e às habilidades motoras. Foram aplicados critérios de inclusão com foco em estudos empíricos envolvendo participantes em idade pré-escolar. Dos 5407 registros inicialmente recuperados, 12 estudos atenderam a todos os requisitos metodológicos e foram incluídos na síntese final. Os resultados sugerem que as habilidades motoras finas estão associadas à representação numérica e à escrita de números, enquanto as habilidades motoras grossas se relacionam com a percepção espacial e a estimativa. Intervenções que combinam atividade física com ensino de matemática demonstraram efeitos positivos na aprendizagem matemática, especialmente em crianças com dificuldades na compreensão dos números. No entanto, devido à heterogeneidade metodológica entre os estudos, não foi possível realizar uma meta-análise. Esses resultados destacam a necessidade de novas pesquisas com desenhos robustos que esclareçam os mecanismos que ligam o desenvolvimento motor e matemático na educação infantil.

**Palabras-chave:** competência matemática; competência motora; infância; habilidades psicomotoras; aprendizagem matemática; desenvolvimento cognitivo.



## INTRODUCTION

The development of mathematical competence in early childhood education has been a central focus in educational research due to its impact on academic performance throughout life (Kim et al., 2018). From a developmental perspective, several studies have shown that the early acquisition of mathematical skills is influenced by multiple factors, including cognitive, environmental, and motor abilities (Fischer et al., 2020; Gashaj et al., 2019).

In recent years, growing interest has emerged in understanding how non-cognitive factors, such as motor competence, may influence mathematical development in early childhood (Beck et al., 2016; Fischer et al., 2020; Chou et al., 2022; Dackermann et al., 2017). The relationship between motor skills and mathematical performance is based on developmental theories suggesting that object manipulation, body control, and spatial orientation may facilitate the understanding of numerical and geometric concepts (Benavides Pando et al., 2024; Moeller et al., 2011). Furthermore, early motor development may serve as a key precursor to the acquisition of numerical and problem-solving skills (Barrocas et al., 2020; Roesch et al., 2024).

Empirical studies have shown that fine motor skills, essential for tasks such as finger counting or number writing, are correlated with emerging mathematical abilities (Fischer et al., 2020; Fischer et al., 2022). Longitudinal studies have found that children with higher levels of fine motor control tend to develop more precise and faster numerical understanding compared to peers with lower motor dexterity (Gashaj et al., 2023; Kim et al., 2018; Beck et al., 2016). Similarly, the relationship between gross motor skills and mathematical ability has been supported by studies indicating that general coordination and physical activity are associated with better performance in mathematics, particularly in spatial understanding and numerical estimation (Chou et al., 2022; Fischer et al., 2020; Gashaj et al., 2019).

There is also consistent evidence that fine motor skills, particularly visuomotor integration, are positively associated with mathematical ability in young children. One study involving 62 preschoolers found that visuomotor integration, measured through tasks such as the “adapted threading test” and the

“adapted visuomotor integration test,” was a significant predictor of mathematical performance (Flores et al., 2023a). Another study involving 81 to 96 children across three age groups (kindergarten, second grade, and fourth grade) found that manual dexterity of the dominant hand in kindergarten and the non-dominant hand in second grade was related to mathematical skills, although this relationship decreased in fourth grade (Gashaj & Trninic, 2023; Roesch et al., 2024).

A meta-analysis of 34 studies involving 78 527 individuals also confirmed a moderate positive correlation ( $r = 0,27$ ) between fine motor skills and mathematical ability, with cultural background and measurement tools influencing the strength of this relationship (Kang & Wen, 2023; Barrocas et al., 2020). This interpretation follows Cohen’s (1988) guidelines for effect size classification.

A large-scale study involving 1072 preschool children aged 5 to 5,9 years revealed that motor skills were strongly associated with simple addition and subtraction tasks, even after controlling for age, sex, and working memory (Wang et al., 2024).

Another study involving 39 kindergarteners found that integrating fundamental motor skills (FMS) with mathematics improved FMS mastery and physical activity levels, although it did not significantly impact mathematical skills (Capio et al., 2024).

Several theoretical models have attempted to explain the underlying mechanisms of this relationship. Some hypotheses suggest that practicing motor activities fosters the development of executive functions, such as working memory and inhibitory control, which play a key role in mathematical processing (Beck et al., 2016; Gashaj et al., 2019). Theories of integrated development suggest that the maturation of motor and cognitive functions is closely linked at the neural level, forming a foundation for the acquisition of academic competencies. This perspective emphasizes the importance of early physical experiences in supporting higher-order cognitive processes such as reasoning and problem-solving (González et al., 2024; Moeller et al., 2011).

Educational interventions have also demonstrated the potential of integrating motor skills with mathematical learning. Recent studies have shown



that programs combining physical activities with mathematics instruction can significantly improve numerical performance and spatial understanding in preschool children (Beck et al., 2016; Fischer et al., 2020; Gashaj et al., 2023; Chou et al., 2022; Dackermann et al., 2017). Furthermore, the use of motor strategies in math instruction, such as finger counting or body-based representation of quantities, has been found to strengthen understanding of basic numerical concepts (González et al., 2024; Fischer et al., 2011; Roesch et al., 2024).

Despite these findings, the evidence remains fragmented and presents discrepancies regarding the strength of the relationship between motor and mathematical competence, as well as the specific mechanisms that explain it (Kim et al., 2018; Fischer et al., 2020; Beck et al., 2016; Benavides-Pando et al., 2024; Flores et al., 2023a). Methodological heterogeneity, differences in sample selection, and variability in assessment tools used make it difficult to compare existing studies (Fischer et al., 2020; Beck et al., 2016; González-Andrade et al., 2024; Gashaj et al., 2019).

Given this context, this systematic review of scientific literature aims to synthesize existing evidence on the relationship between mathematical and motor competence in early childhood education. The most relevant studies will be analyzed, with special emphasis on the measurement instruments used, the types of interventions developed, and the variables that may influence this relationship (Flores et al., 2023b; Kang et al., 2023; Gough et al., 2017).

Despite increasing interest in the connection between physical and cognitive development, the relationship between motor competence and mathematical competence in early childhood remains insufficiently understood. Previous research has employed diverse methodologies and assessment instruments, limiting the comparability and generalizability of findings (Rodríguez-Guerrero et al., 2023; Agirre-Basurko et al., 2021; Arias-Otero & Lafuente-Fernández, 2022). Moreover, the underlying mechanisms, whether cognitive, neurophysiological, or pedagogical, remain unclear (Dackermann et al., 2017; Snyder, 2019; González-Andrade et al., 2024).

Therefore, this systematic review aims to address the following research question: What is the nature and

extent of the relationship between motor competence and mathematical competence in early childhood education?

By synthesizing empirical findings from the past decade, this review seeks to clarify the state of the evidence, identify emerging patterns, and offer educational implications to support early childhood learning from an interdisciplinary perspective (Cecchini & Carriedo, 2020; Hraste et al., 2018; Boat et al., 2022).

This conceptual approach is grounded in the theory of embodied cognition, which provides a foundation for interpreting the relationship between movement and mathematical learning in early childhood.

This systematic review adopts embodied cognition as its theoretical lens to interpret the relationship between motor competence and mathematical competence in early childhood. From this perspective, cognitive development, including mathematical learning, is deeply grounded in sensorimotor experiences and the physical interaction with the environment. Rather than viewing cognition as an isolated mental process, embodied cognition highlights the body's fundamental role in shaping thought and learning.

In the context of early mathematics, children's physical actions, such as manipulating objects, moving through space, or performing coordinated motor sequences, may support their understanding of numerical concepts, spatial relationships, and problem-solving strategies. Several empirical studies support this view, demonstrating that integrating physical activity into mathematics instruction enhances both cognitive performance and academic outcomes (Cecchini & Carriedo, 2020; Magistro et al., 2022; Mavilidi & Vazou, 2021).

For instance, Magistro et al. (2022) found that two years of physically active mathematics lessons improved not only gross motor skills but also cognitive functioning in primary school children. Similarly, Mavilidi & Vazou (2021) showed that classroom-based physical activity can enhance math performance when learning is physically embodied. These results align with the principles of embodied cognition and suggest that motor competence can act as a catalyst for mathematical learning.



By synthesizing empirical findings from the past decade, this review seeks to clarify the state of the evidence, identify emerging patterns, and offer educational implications to support early childhood learning from an interdisciplinary perspective (Cecchini & Carriedo, 2020; Hraste et al., 2018; Boat et al., 2022). Although the existence of a correlation does not imply a causal relationship or the necessity of simultaneous teaching, interdisciplinary approaches may offer meaningful opportunities for integrating motor and mathematical learning within early childhood education.

This review seeks to answer the following research question: What is the nature and extent of the relationship between motor competence and mathematical competence in early childhood education?

## METHODOLOGY

This systematic review was designed to identify, evaluate, and synthesize empirical evidence on the relationship between motor competence and mathematical competence in early childhood education. The review followed the PRISMA 2020 guidelines and methodological frameworks recommended by Gough et al. (2017), ensuring a transparent and replicable process. Each phase of the review, from search strategy to study selection and synthesis, was structured to respond specifically to the research question posed in the introduction.

### Protocol and Records

For the preparation of this systematic review, we followed the PRISMA 2020 reporting guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) as recommended by Page et al. (2021). This study was carried out through a systematic review of the literature with the aim of analyzing the relationship between mathematical competence and motor competence in early childhood education. To ensure a rigorous and evidence-based analysis, the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement were followed, establishing clear criteria for the search, selection, and analysis of the included studies (Snyder, 2019).

### Information Sources

A literature search was conducted in five widely recognized scientific databases in the fields of education, psychology, neuroscience, and sports science (Table 1).

Table 1. Databases consulted and their relevance

Database	Thematic Coverage	Justification for Inclusion
Web of Science (WoS)	Approx. 180 million scientific documents; Social sciences, education, psychology, and neuroscience	Broad coverage of high-impact and peer-reviewed studies
Scopus	Approx. 80 million scientific documents; Multidisciplinary, with an emphasis on social and educational sciences	Index with a large number of relevant studies in education and child development
Dialnet	Approx. 9 million scientific documents; Scientific literature in Spanish	Allows the inclusion of studies in Spanish, broadening the diversity of sources
PsycINFO	Approx. 6 million scientific documents; Psychology and developmental neuroscience	Key database for studies on child development and cognition
ERIC (Education Resources Information Center)	Approx. 2 million scientific documents; Education and learning	Main source of peer-reviewed educational research

Source: Own elaboration

### Search

For document search, the following search terms were used in the title, abstract, and keyword fields, combining them with Boolean operators to maximize the retrieval of relevant information (Table 2).

Table 2. Search Strategy and Applied Filters



Search Terms	Applied Filters
“Math” AND “Psychomotor skills”	Peer-reviewed studies only
“Math” AND “Physical activity”	Languages: English, Spanish, and Portuguese
“Math” AND “Motor Skills”	Full-text access available
“Math” AND “Physical education”	Publications between 2010 and 2024

Source: Own elaboration

The choice of databases (ERIC, PsycINFO, Scopus, Web of Science, and Dialnet) was based on their relevance to educational and psychological research. These sources cover peer-reviewed literature in early childhood education, developmental psychology, and psychomotor development, ensuring a comprehensive retrieval of relevant studies. The search strategy was designed to maximize sensitivity and specificity by combining descriptors related to motor skills, mathematics, and early education.

**Eligibility Criteria**

Specific filters were established to ensure the relevance and quality of the retrieved articles:

- Only peer-reviewed scientific articles were included.
- Studies were limited to those published in English, Spanish, and Portuguese.
- Priority was given to studies published between 2010 and 2024; however, earlier studies were considered if especially relevant to the topic.
- Only studies with full-text access were considered.

To ensure the validity of the selected studies, inclusion and exclusion criteria were defined, as detailed in Table 3.

*Table 3. Publication Selection Process and Inclusion and Exclusion Criteria*

Inclusion Criteria	Exclusion Criteria
Empirical studies analyzing the relationship between mathematical competence and motor competence.	Studies focused on populations outside early childhood education.

Research conducted with children aged 3 to 6 years (Early Childhood Education).	Theoretical reviews without empirical evidence.
Studies using standardized instruments to assess mathematical and motor skills.	Studies without full-text access.
Articles published between 2010 and 2024.	Studies with low methodological rigor or without quantitative statistical analysis.

Source: Own elaboration

**Study Selection**

The study selection process was carried out in several phases:

- Initial search: 5407 records were identified in the selected databases.
- First filter: Articles that did not meet the inclusion criteria were removed, reducing the sample to 122 studies.
- Duplicate removal: A process to eliminate duplicate studies was applied, resulting in 45 unique studies.
- In-depth review: Abstracts and full texts of the 45 selected studies were analyzed.
- Final selection: 12 studies that met all methodological and substantive criteria were included.

The three authors conducted the selection and exclusion of studies collaboratively. All authors independently reviewed titles, abstracts, and full texts based on the inclusion and exclusion criteria. Disagreements were discussed collectively until a consensus was reached, ensuring transparency and rigor throughout the selection process.

Below is the PRISMA flow diagram detailing the selection process (Figure 1).

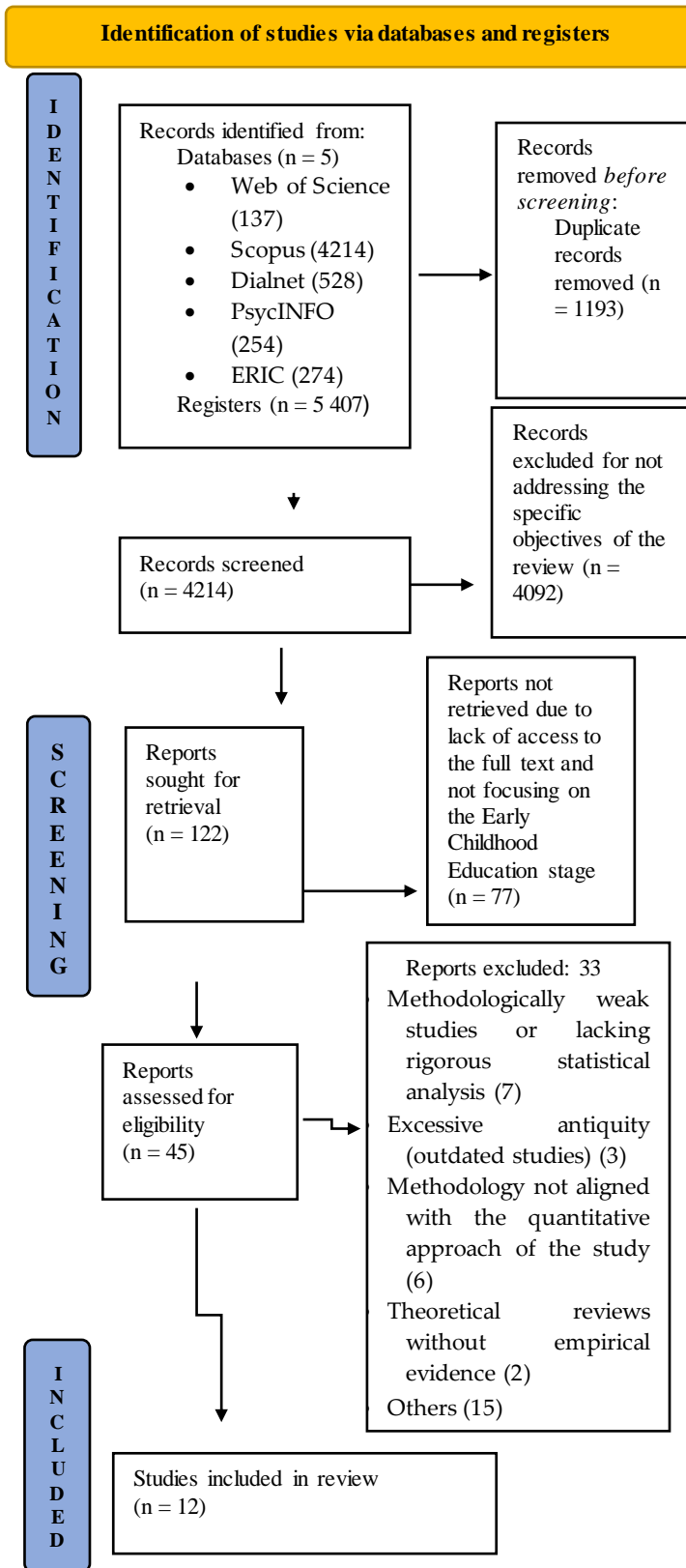


Figure 1. Systematic Review PRISMA Flow Diagram

To manage references and streamline the selection process, the RefWorks citation management tool was used. This software facilitated the organization of records, the removal of duplicates, and the storage of bibliographic data throughout the review process.

Since RefWorks integrates all imported references into a unified database, it was not possible to track the number of remaining records by individual source after the removal of duplicates. Therefore, although the PRISMA diagram reflects the total number of records identified and retained, disaggregated data by database could not be reported.

**Data Extraction and Analysis Process**

For data extraction and organization, a matrix was created using Microsoft Excel, where key variables from each selected study were compiled, distinguishing between:

- Substantive variables: Year of publication, authors, journal, country of origin of the study.
- Methodological variables: Study objective, type of research (cross-sectional, longitudinal, experimental, correlational), sample size, participants’ gender, ages, assessment instruments, main results, and conclusions.

This procedure enabled a structured synthesis of the findings, facilitating the identification of trends and gaps in the existing literature. Although this review did not include a formal risk-of-bias assessment using a standardized tool, the selection and interpretation of studies were guided by criteria such as clarity of objectives, methodological transparency, and relevance to the research question. We acknowledge that the absence of a formal quality appraisal is a limitation of the present review and encourage future studies to incorporate structured tools for evaluating study rigor.

**Ethical Considerations**

Since this study constitutes a systematic literature review, no direct interventions with human participants were conducted. Nevertheless, the ethical principles relevant to documentary research were rigorously followed, following the recommendations for academic integrity and good scientific practices.

The study received ethical approval from two independent committees:



- First, the EDUCA Ethics Committee (authorization code: 05/2025), an independent committee composed of university professors that evaluates educational research protocols.
- Second, the Ethics Committee for Research and Teaching of the University of A Coruña (CEID-UDC), which issued a favorable opinion on the project entitled “*Study and analysis of the relationship between Mathematical Competence and Motor Competence in final-year preschool children*” (Record number: 2024-031, version 2).

In addition, the following ethical safeguards were implemented:

- Intellectual property rights were respected through the proper citation of all consulted sources.
- All forms of plagiarism were avoided through the use of detection software and strict adherence to citation standards.
- Objectivity and transparency were ensured in the selection and analysis of studies, avoiding biases in the interpretation of results.

This approach ensures that the findings are valid, reproducible, and ethically sound, thereby contributing to the advancement of knowledge at the intersection of mathematics education and motor development within educational contexts in early childhood.

#### **Bias assessment, measures of effect, and synthesis procedures**

We did not use a specific tool to assess risk of bias in each of the included studies. However, general methodological criteria were taken into account to exclude research that did not meet minimum quality standards, such as the absence of quantitative statistical analysis, lack of validated instruments, or designs without experimental control. The selection and analysis of the studies was carried out by a lead reviewer, with methodological supervision by the research team. As a meta-analysis was not conducted, we did not calculate aggregate effect measures such as mean differences or risk ratios. Instead, the results presented in each study were extracted and synthesized, considering the significant results reported by the authors themselves.

To decide which studies were eligible for inclusion in the narrative synthesis, a comparative table was developed with the substantive and methodological characteristics of each research (see Table 4).

No data transformations or statistical conversions were required, as most studies reported basic qualitative or quantitative results. The synthesis of the findings was organized according to the variables analyzed (fine motor skills, gross motor skills, executive functions) and their relationship with mathematical competence. For the presentation of results, a structured table was used that systematically collects the most relevant data of each article. A meta-analysis was not carried out due to the methodological heterogeneity of the studies (designs, instruments, ages and contexts). Neither statistical models were applied to explore heterogeneity nor were sensitivity analyses performed. The results were integrated through a narrative synthesis aimed at identifying common patterns, gaps in the literature and possible implications for educational practice.

A formal assessment of publication bias was not conducted. However, efforts were made to minimise this risk by including large databases and studies in several languages (English, Spanish and Portuguese), as well as both positive and inconclusive research.

We did not apply specific tools to assess certainty or degree of confidence in the body of evidence. However, the overall methodological quality of the studies and the consistency of results across investigations were taken into account in formulating conclusions.

#### **REVIEW RESULTS**

The results obtained from the systematic review are presented below (Table 4), organized into different sections that reflect the main trends identified in the literature regarding the relationship between mathematical competence and motor competence in early childhood education. The findings are analyzed in relation to the relation of fine and gross motor skills on mathematical learning, the role of executive functions, and the effectiveness of educational programs that integrate physical activity and mathematics instruction.

*Table 4. Analysis of Articles Providing Scientific Evidence*



Authors	Year	Objective	Type of Study	Sample and Gender	Variables	Instruments Used	Results	Conclusions
Beck, Lind, Geertsen, Ritz, Lundbye-Jensen & Wienecke	2016	To investigate whether the integration of fine and gross motor activities in mathematics lessons improves mathematical performance in children	Quasi-experimental, quantitative, with intervention and control groups	165 children (7,5 years old, 77 girls and 88 boys)	Fine and gross motor skills, mathematical performance, visuospatial memory, executive functions	Standardized mathematical test of 50 tasks, visuospatial memory and motor skills tests	Gross motor activities significantly improved short-term math performance compared to traditional teaching and fine motor intervention	Integrating gross motor activities into math instruction can improve learning in children, especially those with normal math performance
Benavides Pando, Jiménez Lira, Paz García, Susperregu y, Palma Gardea & Mondaca Fernández	2024	To examine the relationship between gross, fine, and perceptual-motor skills and symbolic numerical skills in Mexican preschool children	Observational, quantitative	123 preschool children (73 girls, 50 boys) aged 3 to 5 years	Gross, fine and perceptual-motor skills; symbolic numerical skills; inhibitory control; visuospatial working memory	Motor skills tests (Battelle Development Inventory, BDI-2), symbolic numerical skills tests (problem solving and numerical comparison), inhibitory control tests (Stroop Test) and visuospatial working memory (Corsi Block Tapping Test)	The comparison of symbolic numbers was associated with perceptual-motor skills; Mathematical problem solving was related to precursor numeracy skills, but not to motor skills	Perceptual-motor skills play a key role in the acquisition of numerical concepts in early childhood



Cecchini & Carriedo	2020	To examine the effects of an interdisciplinary approach that integrates physical education and mathematics on physical activity and subtraction learning in first-graders	Quasi-experimental, quantitative, with intervention and control groups	46 first-grade children (19 boys, 27 girls) with a mean age of 76,98 months	Light and moderate-vigorous physical activity, sedentary behavior, learning subtraction	ActiGraph-GT3X accelerometers to measure physical activity, primary math knowledge test to evaluate subtraction	Students in the interdisciplinary group achieved greater physical activity, less sedentary behavior, and better subtraction results compared to the traditional teaching group	Integrating physical activity into math teaching improves learning and reduces sedentary behavior in children
Chou, Hu, Winsler, Wu, Greenburg & Kong	2022	To examine the relationship between physical fitness, motor competence, executive functions, and academic performance in Chinese preschool children	Longitudinal, quantitative	273 preschool children from 30 schools (141 boys, 132 girls)	Fitness, Motor Competence, Executive Functions, Receptive Language, Math, Science	Physical Fitness and Motor Assessments, Executive Function Test (HTKS), Receptive Language and Math Assessments	Physical fitness predicts academic performance at the school level; Motor competence predicts academic performance within each school through the mediation of executive functions	Motor competence and physical fitness are important for academic development in preschoolers, highlighting the need to promote physical activity in early childhood
Elofsson, Bohm, Jeppsson & Samuelsson	2018	To evaluate the effectiveness of the "Math in Action" method (physical activity and music) in the mathematical learning of preschool children	Experimental, quantitative	53 preschool children (28 girls, 25 boys), 5,82 years average. No control group was established.	Physical activity, music, math skills (counting, numeracy, numeracy)	Tests of numerical knowledge, estimation on the number line, verbal addition and subtraction	Children who learned math with physical activity and music improved significantly more than those with traditional instruction	Integrating Physical Activity and Music in Math Teaching May Benefit Math Development in Preschoolers



Fischer, Suggate & Stoeger	2020	To analyze the relationship between fine motor skills and the development of finger-based number representations in preschoolers	Quantitative, correlational	80 preschool children (40 boys, 40 girls)	Fine motor skills (dexterity, graphomotor skills), finger-based numerical representations (ordinal and cardinal), working memory	Manual dexterity tests (bead threading, coin posting), numerical representation tasks with fingers, working memory tests and numerical skills	Manual dexterity is related to finger-based numerical representations and, through them, influences numerical skills. However, this relationship disappears when cognitive skills such as visuospatial working memory are controlled	Manual dexterity could facilitate the formation of early number representations, suggesting that educational interventions should integrate motor activities into mathematical learning in preschoolers
Flores, Coelho, Mourão-Carvalho & Forte	2023	Identify motor skills most associated with math performance in typically developing preschoolers	Systematic review	18 reviewed studies	Fine and gross motor skills, visual-motor integration, mathematical performance	Various measurement instruments were analysed in the included studies	Positive associations were found between fine motor skills (fine motor coordination and visual-motor integration) and mathematical performance, especially in numerical counting tasks	Early identification of children with fine motor skills difficulties can help design more effective strategies for teaching math



Jylänki, Sääkslahti & Aunio	2024	To assess the effects of a combined fundamental motor skills and early numeracy (MovEN) intervention in children with poor mathematical achievement	Quasi-experimental, quantitative, with intervention and control groups	50 pre-school children from six schools in Finland (29 girls, 21 boys)	Fundamental motor skills, early numeracy, mathematical problem solving, individual factors (executive functions, language, socioeconomic status)	Early Numeracy Test, Mathematical Problem-Solving Measure, Motor Skills Test (KTK), Executive Function and Language Skills Tests	The MovEN intervention significantly improved early math skills and math problem-solving, while the motor skills intervention improved motor skills alone	The combination of motor skills and mathematical learning is effective in improving multiple skills in preschoolers, suggesting the need for holistic interventions in early childhood education
Kim, Duran, Cameron & Grissmer	2018	To examine the dynamic and reciprocal relationships between visual-motor integration, attention, fine motor coordination, and mathematical skills in pre-school children	Longitudinal, quantitative	135 kindergarteners and 119 first-graders (co-educational) in the U.S.	Visual-motor integration, attention, fine motor coordination, math skills	NEPSY (Neuropsychological Assessment), KeyMath-3 Diagnostic Assessment	Visual motor integration and mathematics showed reciprocity in kindergarten and first grade. Attention contributed to math learning at both levels, and fine motor coordination influenced math indirectly through visual-motor integration	Visual-motor integration and attention are key in mathematical development in early childhood; Fine motor skills contribute indirectly through visual-motor integration



Nesbitt, Fuhs & Farran	2018	Examine the coevolution of visual-motor integration, executive functions, and math performance from prekindergarten through the end of first grade	Longitudinal, quantitative	1138 children in prekindergarten (USA), co-ed	Math skills, visual-motor integration, executive functions	Woodcock-Johnson III Problemas Aplicados, Conceptos Cuantitativos, Bloques de Corsi, Clasificación de Tarjetas de Cambio Dimensional, Cabeza-Pies-Rodillas-Hombros, Golpeteo de Clavijas, Prueba de Diseño de Copia	A bidirectional relationship was found between mathematical skills and executive functions up to first grade. Visual-motor integration predicted math only in prekindergarten	Visual-motor integration and executive functions are fundamental in mathematical development, but the influence of visual-motor integration seems to diminish over time. A comprehensive educational approach that includes motor and cognitive development is recommended
Rodríguez-Guerrero, Gil-Madrona, León & Vásquez-Cruz	2023	To examine the relationship between fine and gross motor skills and language and mathematics development in children in the Colombian Caribbean	Correlational, quantitative, descriptive	219 preschool children (105 boys, 114 girls)	Fine and gross motor skills, language development, math skills	Psychomotor Development Test (TEPSI) for motor skills and language, Utrecht Early Numeracy Test (ENT) for math skills	Positive and significant correlations were found between motor skills and mathematical and linguistic development, although mostly of moderate intensity. Gross motor skills were more closely related to mathematical development than fine motor skills	In children in the Colombian Caribbean, gross motor skills appear to play a more influential role in language and math development than fine motor skills. It is recommended to include motor activities in early childhood education to strengthen this learning



Sneck, Viholainen, Syväoja, Kankaapää, Hakonen, Poikkeus & Tammelin	2019	To systematically examine the effects of school physical activity interventions on mathematical performance in children	Systematic review and meta-analysis	29 studies reviewed (11 264 children aged 4-16 years)	School physical activity, mathematical performance, executive functions, visual-motor integration	Analysis of previous studies with standardized tests in mathematics and physical activity measurement	45% of the studies showed positive effects of physical activity on mathematics, 52% showed no significant effects, and only one study reported a negative effect in a subgroup	Including physical activity in the school day can improve mathematical performance or have no negative effects. It is recommended to continue exploring which types of physical activity are most effective in enhancing mathematical learning
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Source: Own elaboration



In order to provide a cross-study synthesis beyond the descriptive analysis presented in Table 4, we constructed a summary table (Table 5) that classifies and compares the key findings of the reviewed studies. This table presents the types of motor skills assessed (e.g., fine, gross, perceptual), the mathematical domains involved (e.g., number representation, problem-solving), the overall consistency of the findings, the main contradictions or gaps reported, and a qualitative assessment of the strength of the evidence. Table 5 offers a broader comparative perspective that facilitates interpretation and helps identify areas for future research.

Table 5. Synthesis of Key Findings Across Studies

Study	Key Objective	Summary of Findings	Educational Implications
Beck et al. (2016)	Investigate whether fine and gross motor activities integrated into math lessons improve performance	Gross motor activities significantly improved short-term math performance compared to fine motor or traditional instruction	Incorporating gross motor activities into math teaching may enhance learning in typical students
Benavides Pando et al. (2024)	Explore relation between different motor skills and symbolic numerical skills in preschoolers	Symbolic number comparison linked to perceptual-motor skills; problem-solving linked to numeracy, not motor	Perceptual-motor skills are key to acquiring numerical concepts in early childhood
Cecchi ni & Carriedo (2020)	Examine the impact of integrating physical activity into math on learning subtraction and physical activity	Interdisciplinary group had better subtraction results and more physical activity than control	Combining physical education and math boosts both academic and physical outcomes
Chou et al. (2022)	Analyze how fitness, motor competence and executive function relate to academic skills		Physical fitness, motor competence and executive function relate to academic skills
Elofsso n et al. (2018)	Evaluate the 'Math in Action' method combining physical activity and music in preschool		Children with physical activity and music improved significantly in early math tasks
Fischer et al. (2020)	Analyze relationship between fine motor skills and finger-based number representations in preschool		Manual dexterity supported finger-based number representations; effect disappears when WM is controlled
Flores et al. (2023b)	Identify motor skills most associated with math performance in typically developing preschoolers		Fine motor coordination and visual-motor integration positively associated with math performance
Jylänki et al. (2024)	Assess effects of MovEN program combining motor skills and numeracy training		MovEN program improved math skills and problem-solving; motor-only group improved motor skills only
Kim et al. (2018)	Examine reciprocal relationships among visual-motor integration, attention, fine		Visual-motor integration and math show reciprocal relationship; attention and
			programs may enhance cognitive and academic development in preschoolers
			Music and movement activities support math learning in preschool classrooms
			Motor activities may help form early number representations; interventions should integrate both
			Early detection of fine motor difficulties can improve math instruction strategies
			Holistic programs combining math and movement are effective for low-performing preschoolers
			Developing visual-motor and attentional skills supports early math competence



	motor coordination, and math	fine motor indirectly support math	
Nesbitt et al. (2018)	Explore coevolution of visual-motor integration, executive functions, and math performance from pre-K to grade 1	Visual-motor integration predicted math only in pre-K; EF predicted math throughout	Integrated cognitive and motor support strategies recommended from early stages
Rodríguez-Guerrero et al. (2023)	Analyze relationships between fine/gross motor skills and language/math in children in Colombian Caribbean	Gross motor skills more strongly related to math than fine motor; correlations moderate	Include motor activities in early education to support math and language development
Sneck et al. (2019)	Examine effects of school physical activity interventions on children's math performance	45% of studies showed positive effects of physical activity on math, 52% no effect, 1 study negative	Explore which types of physical activity most benefit math learning in schools

Source: Own elaboration

### Relationship between motor skills and mathematical competence

The studies reviewed have provided significant evidence on the relationship between motor skills and mathematical performance in early childhood education. Fine motor skills and gross motor skills have been identified as playing a crucial role in the development of early mathematical skills (Fischer et al., 2020; Benavides-Pando et al., 2024). In particular, fine motor skills have been related to the management of numerical representations (such as the use of fingers to count), while gross motor skills are more linked to spatial understanding and numerical estimation (Chou et al., 2022). The findings indicate that structured physical activity can contribute to the development of mathematical skills

by stimulating visuospatial memory, inhibitory control, and strategic planning (Beck et al., 2016).

### Relation of fine motor skills on mathematical learning

Several studies have shown that fine motor coordination is closely related to the acquisition of mathematical skills in preschoolers (Kim et al., 2018; Fischer et al., 2020). Manual dexterity influences tasks such as writing numbers and the use of manipulative material in solving mathematical problems (Flores et al., 2023a). In longitudinal studies, fine motor skills have been found to predict mathematical performance even after controlling for other cognitive variables such as working memory (Nesbitt et al., 2018).

Overall, the reviewed studies consistently show that fine motor coordination is positively associated with early numeracy skills, particularly in tasks involving number recognition, writing, and manipulation of materials. However, variation in the instruments used to assess motor skills limits comparability.

### Impact of gross motor skills on mathematical competence

The role of physical activity and gross motor skills in math learning has been examined in several studies, with consistent findings suggesting that structured motor activity can improve performance on math tasks (Cecchini & Carriedo, 2020). Studies that have integrated physical activity into mathematics teaching have shown improvements in understanding spatial concepts and mathematical problem solving, especially in children with low academic performance (Jylänki et al., 2024). Some studies have explored interventions based on physical play, finding that children who participate in guided motor activities have significant improvement in numerical conceptualization and mental calculation (Elofsson et al., 2018).

### Effect of executive functions on the relationship between motor skills and mathematics

Executive functions (EF) have been identified as mediating the relationship between motor skills and mathematical performance (Kim et al., 2018; Nesbitt et al., 2018). In particular, it has been found that:



- Inhibitory control and working memory are directly related to mathematical problem-solving ability (Chou et al., 2022).
- Visual-motor integration is a key factor in the relationship between motor skills and numerical performance (Rodríguez-Guerrero et al., 2023).

These findings suggest that motor development not only directly impacts mathematical learning but also influences key cognitive skills for numerical reasoning.

### Educational Programs and Interventions

The implementation of educational programs that combine mathematics and physical activity has been shown to be effective in improving mathematical learning in early childhood education (Sneck et al., 2019). Studies have explored various methodologies, including:

- Interventions based on structured motor games (Beck et al., 2016).
- Use of digital tools and exergames to improve mathematical understanding through physical activity (Cecchini & Carriedo, 2020).
- Hybrid approaches that combine traditional teaching with motor activities in mathematical problem solving (Jylänki et al., 2024).

Overall, the evidence reviewed suggests that motor competence, both fine and gross, has a significant impact on the development of mathematical skills in early childhood education. It has been identified that fine motor skills are related to accuracy in counting and writing tasks, while gross motor skills favor spatial understanding and numerical estimation. In addition, the role of executive functions in this relationship highlights the need for educational approaches that integrate motor and cognitive development into mathematics teaching.

Educational programs that incorporate physical activity into math instruction have been shown to be effective, particularly in children with numeracy difficulties. However, more research is required to determine which types of motor activity are most

beneficial and how they can be optimally integrated into educational curricula.

Finally, these findings underscore the importance of fostering a holistic educational approach that combines motor, cognitive, and mathematical development in early childhood education.

### Study quality assessment and evidence synthesis

A qualitative evaluation was carried out based on general methodological criteria. Papers that did not present clear analysis procedures, validated instruments, or a design that guaranteed the reliability of the results were excluded. Consequently, most of the included studies met basic standards of methodological quality, although some showed limitations such as reduced sample sizes or lack of experimental control.

The narrative synthesis was structured according to the types of motor skills studied (fine motor skills, gross motor skills, visuomotor coordination) and their relationship with different aspects of mathematical performance. Most of the studies reviewed presented quantitative designs, although heterogeneous in terms of instruments, contexts and methodologies used. This methodological variability limited the possibility of making direct quantitative comparisons. No meta-analysis was performed, so no aggregate measures of effect or confidence intervals are presented. In addition, no subgroup analyses were carried out and no causes of heterogeneity were explored using statistical techniques. The diversity of methodological approaches was considered as one of the main sources of heterogeneity between studies.

A comparative analysis of the findings was performed between studies with different methodological designs, samples, and contexts, in order to identify recurring patterns and consistent trends in the available evidence. We included research that reported positive, negative, and inconclusive results, which helps mitigate the risk of publication bias and provides a more balanced view of the phenomenon studied. Conclusions were drawn based on the convergence of results, the overall methodological quality of the studies, and the degree of replicability observed between studies addressing similar variables. Taken together, the consistency of the findings supports the validity of the trends identified in the review.



In summary, both fine and gross motor skills are associated with mathematical performance in early childhood, but through distinct mechanisms. Fine motor skills appear to support symbolic processes (e.g., number writing), while gross motor skills relate more closely to spatial and executive functions. Some studies found inconsistent results, especially when controlling for other cognitive variables, suggesting a need for further clarification.

## DISCUSSION

The findings obtained in this systematic review reinforce the idea that motor competence and mathematical competence are interrelated throughout all educational stages, from early childhood education to higher education. However, detailed analysis of the literature reveals significant variations in methodological approaches, in the way this relationship is conceptualized, and in the results obtained, suggesting the need for a more robust theoretical framework that explains these connections in a comprehensive manner (Kim et al., 2018; Nesbitt et al., 2020; Have et al., 2016; González-Andrade et al., 2024).

Several studies have shown that fine motor skills play a key role in the acquisition of mathematical skills, particularly in number recognition, number writing, and basic mathematical problem solving at an early age (Fischer et al., 2020; Gashaj et al., 2019; Luo et al., 2007). In early childhood and primary education, this relationship has been widely documented, showing that manual dexterity contributes significantly to numerical representation and the automation of arithmetic processes (Benavides-Pando et al., 2024; Kim et al., 2018; Rodríguez-Martín & Buscà-Donet, 2022).

On the other hand, gross motor skills seem to be more linked to spatial cognition, numerical estimation, and geometric problem-solving at all educational stages (Chou et al., 2022; Hraste et al., 2018; Scott et al., 2024). In primary education, it has been observed that children with greater motor coordination development perform better in understanding numerical magnitudes and solving spatial problems (Rodríguez-Guerrero et al., 2023; Cecchini & Carriedo, 2020; Fakri & Hashim, 2020). In secondary and higher education, the relationship between gross motor skills and mathematical competence is still evident, although mediated by

other factors such as executive function and abstract reasoning ability (Sneck et al., 2019; Flores et al., 2023b; Syväoja et al., 2021).

The integration of physical activity in the teaching of mathematics has been a recurrent strategy in the literature reviewed. Interventions based on interdisciplinary approaches have shown benefits in both learning mathematical concepts and improving executive function in children and adolescents (Cecchini & Carriedo, 2020; Lubans et al., 2018; Daly-Smith et al., 2021; Boat et al., 2022). However, in secondary and higher education, these effects have been less studied, although it has been reported that aerobic exercise and structured motor activities can improve sustained attention and complex problem-solving in advanced mathematics (Beck et al., 2016; Sneck et al., 2019; Wang & Chen, 2023).

From a practical perspective, the implementation of interventions that combine physical activity with mathematics teaching faces logistical and structural challenges in education systems. The lack of teacher training in interdisciplinary approaches, the rigidity of school curricula, and the limited availability of resources can make it difficult to adopt methodologies that integrate movement into mathematical learning in an effective and sustainable way (Agirre-Basurko et al., 2021; Arias-Otero & Lafuente-Fernández, 2022). These obstacles suggest the need to design specific training programs for teachers, as well as to make curricular structures more flexible to favor the inclusion of active methodologies in the classroom.

Another relevant aspect that has emerged in this review is the influence of the educational and social context on the relationship between motor skills and mathematics. Studies conducted in different countries have found variations in outcomes depending on the school curriculum and the motor learning opportunities provided to students (González-Andrade et al., 2024; Domazet et al., 2016). In settings where physical education plays a more relevant role in the curriculum, the positive effects on mathematical performance appear to be more pronounced, especially in primary and secondary education (Jylänki et al., 2024; Have et al., 2018).

In higher education, the relationship between motor activity and mathematical performance has been less



explored, although some studies have pointed out that university students who exercise regularly tend to perform better on tasks that require logical reasoning and mathematical problem-solving (Fischer et al., 2020; Zhang et al., 2024). In addition, physical activity has been associated with improvements in emotional regulation and stress management, factors that can influence performance in mathematics and other scientific disciplines (Chou et al., 2022; Wienecke et al., 2021).

Despite these advances in research, gaps persist in the literature. First, there is a lack of longitudinal studies that analyze the evolution of the relationship between motor skills and mathematics over time and at all educational stages (Sember et al., 2022; Have et al., 2016). Second, the heterogeneity of the assessment instruments makes it difficult to compare and synthesize results, which highlights the need to develop standardized tools to measure both competencies uniformly in pre-school, primary, secondary, and higher education (Nesbitt et al., 2018; Kim et al., 2018).

On the other hand, it is essential to further explore the mediating role of executive functions in this relationship, given that several studies have suggested that these cognitive skills may influence the way motor skills impact mathematical learning (Mavilidi & Vazou, 2021; Magistro et al., 2022; Sartori et al., 2022). Inhibitory control and working memory have been identified as directly related to mathematical problem-solving ability at all educational stages (Chou et al., 2022; Rodríguez-Guerrero et al., 2023; Syväoja et al., 2021).

In addition, the relationship between motor skills and mathematics in secondary and university education could be mediated by active lifestyle and study habits. It has been observed that students with higher levels of physical activity have better attention span, information processing, and metacognitive skills, which can have a positive impact on their overall academic performance, including mathematics (Beck et al., 2016; Suárez-Manzano et al., 2024).

In terms of educational applications, the findings of this review suggest that the implementation of active methodologies in mathematics teaching could benefit students of all ages. Strategies such as the use of motor games in pre-primary and primary education,

active breaks in secondary school, and structured exercise programs at university could contribute to the improvement of mathematical learning and the development of transversal cognitive skills (Elofsson et al., 2018; Fischer et al., 2020).

Therefore, although existing evidence supports the interconnection between motor competence and mathematical competence at all educational stages, it is crucial to continue exploring the underlying mechanisms that explain this relationship. The variability in the findings reflects the need to unify methodological approaches, expand the range of longitudinal studies, and consider the role of contextual variables that may be modulating the observed effects. The development of pedagogical models that integrate physical activity and mathematics teaching could represent a promising strategy to optimize learning from infancy to higher education, providing both academic benefits and the general well-being of students.

#### LIMITATIONS OF THE STUDY

Despite the findings obtained in this systematic review, it is essential to recognize a series of methodological and conceptual limitations that may have influenced the interpretation and generalization of the results. These limitations underscore the need to further deepen the relationship between motor competence and mathematical competence in early childhood education through more rigorous and methodologically sound studies.

One of the main limitations of this study lies in the heterogeneity of the included studies. Despite having conducted an exhaustive search in various databases, the variability in methodological approaches, research designs and measurement instruments used makes it difficult to directly compare the findings. In particular, significant differences were observed in the way in which both mathematical and motor competence were assessed, which limits the possibility of establishing generalizable conclusions that can be extrapolated to different educational contexts.

In addition, most of the studies reviewed employ cross-sectional designs, which prevents establishing solid causal relationships between motor development and mathematical performance. The absence of longitudinal studies limits the



understanding of the evolution of this relationship over time and of the sustained impact of interventions that combine physical activity and mathematics teaching. To strengthen the validity of the findings, it is essential to develop longer studies that allow us to analyze how motor skills influence mathematical learning throughout childhood and whether this influence is maintained in later educational stages.

Another important limitation is related to the control of extraneous variables that could be modulating the relationship between motor skills and mathematics. Factors such as socioeconomic level, family environment, quality of teaching and student motivation have not been addressed uniformly in the studies analysed, which may introduce biases in the interpretation of the results. The lack of rigorous control over these variables makes it impossible to determine precisely to what extent motor skills are an independent factor that influences mathematical performance or whether it is mediated by other contextual and personal aspects.

Article selection bias is another limitation to consider. Despite strict inclusion and exclusion criteria, there is a possibility that some relevant studies may not have been considered due to language restrictions, access to databases, or limitations on the search terms used. In addition, although articles in English, Spanish, and Portuguese have been included, most of the studies reviewed come from Western countries, which could limit the applicability of the findings to more diverse educational and cultural contexts.

In future research, it will be essential to address these limitations by developing longitudinal studies, standardizing assessment instruments, considering contextual variables, and including more globally representative samples. It will also be key to analyse the long-term effects of educational interventions that combine physical activity and mathematics, especially in populations with learning difficulties, in order to generate more effective pedagogical models that are adaptable to different educational contexts.

## CONCLUSIONS

This systematic review examined the relationship between motor competence and mathematical

competence in early childhood education, revealing a consistent and significant association between both domains. The findings emphasize that motor development, particularly fine motor skills, plays a crucial role in the acquisition of early mathematical abilities.

Specifically, fine motor skills were consistently linked to numerical recognition, number writing, and the manipulation of mathematical materials, while gross motor skills appeared more closely associated with spatial cognition, numerical estimation, and geometric reasoning. These differentiated contributions support the notion that both types of motor competence influence mathematical development through distinct but complementary pathways.

Moreover, several studies highlighted the potential mediating role of executive functions, such as working memory, attentional control, and cognitive flexibility, in the relationship between motor and mathematical skills. These cognitive processes may explain how motor development indirectly enhances mathematical problem-solving and strategic planning abilities.

Despite the promising evidence, significant methodological variability was observed across the reviewed studies. Differences in research designs, sample characteristics, and particularly in the assessment tools used limit the comparability of results and the ability to draw strong conclusions. The scarcity of longitudinal studies also hinders the establishment of causal inferences and a better understanding of the developmental trajectory of this relationship.

From an educational perspective, the findings of this review offer important pedagogical implications. Incorporating structured motor activities, especially those aimed at developing fine motor skills, into mathematics instruction right enhance early numeracy. Interdisciplinary interventions that integrate movement and mathematical learning have demonstrated positive effects, particularly in children with learning difficulties. Furthermore, promoting active learning strategies that engage the body as well as the mind can foster both academic achievement and children's holistic development.



In summary, the integration of motor and mathematical competence in early childhood education emerges as a promising area for both research and practice. Future studies should aim to use standardized and validated assessment instruments, adopt longitudinal designs, and further explore the mediating role of executive functions to deepen our understanding of the mechanisms underlying this relationship.

### OTHER INFORMATION

This systematic review was not registered in any official database or in specialized registries in systematic reviews, such as PROSPERO. Likewise, a formal protocol was not developed prior to its execution. Consequently, no modifications or amendments were made to pre-existing records or protocols, as there was no reference documentation of this type.

This research did not have specific funding from public agencies, private entities or non-profit organizations. The development of the study is framed within the authors' research activity. No external institutions were involved in the design, development, analysis or dissemination of the results of this review. The authors declare that they have no conflict of interest in relation to the content of this work.

The data extracted from the included studies, as well as the matrix used for the organization and coding of the information, are available upon reasoned request to the research team. No computer codes or advanced statistical software were used, since the methodological approach adopted was eminently descriptive and narrative.

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